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On Incidence of Diarrhoea among Children in India
Can the Gordian Knot of Complementarities Be Cut?

Arijita Dutta, Gitanjali Hajra, Shyama V Ramani

Drinking water, sanitation and hygiene behaviour, referred to as the WASH variables by the United Nations Children's Emergency Fund, are acknowledged as the three main determinants of diarrhoeal diseases. But the impact of their complementarities on disease incidence remains understudied. This study uses state and household level data to examine the determinants of child diarrhoeal incidence. It introduces indicators of WASH quality and combined presence, both at the household and state levels. It combines them in a novel analysis to understand their roles. In the Indian states, with the worst WASH infrastructure, these variables are strategic substitutes, but as WASH infrastructure improves, they become strategic complements. Thus, resource allocation to lower diarrhoea incidence must take into account the complementary rather than individual presence of these focal variables. Further, the quality of WASH also matters. The Swachh Bharat Abhiyan, targeting universal sanitation coverage, is unlikely to be effective unless it breaks the Gordian knot of complementarities and WASH quality holding up the burden of childhood diarrhoea.

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Arijita Dutta (*dutta.arijita@gmail.com*) and Gitanjali Hajra (*gitu.hajra@gmail.com*) are with the Department of Economics, University of Calcutta, Kolkata, and Shyama V Ramani (*ramani@merit.unu.edu*) is with the United Nations University-Merit, Maastricht, Netherlands.

Diarrhoeal disease is one of the most significant and leading causes of child mortality and morbidity in low income countries of the world (UNDP 2014). According to the World Health Organization's (WHO) estimates, every year, diarrhoea is responsible for approximately eight lakh deaths of children under the age of five, mostly in developing countries (WHO 2007). About 88% of this incidence is related to unsafe water supply, inadequate sanitation and/or hygiene behaviour (WHO 2004). Many developing countries have been investing in sanitation, water and education infrastructure to lower diarrhoea incidence, especially over the last two decades. But they have not been very successful as the disease still claims 2,195 children every day, even more than HIV, malaria and measles combined (Liu et al 2012). The loss and/or debilitation of children are of concern not only from the point of welfare, but also for economic growth and inclusive development.

This article provides some insight on the policy initiatives to slash diarrhoea incidence by examining the role of public health infrastructure and its interrelationships with the hygiene behaviour of households. It starts from the premise that an inadequate understanding of the interrelationships between complementary determinants of diarrhoea is leading to sub-optimal policy design and implementation, which, in turn, gives rise to heterogeneous outcomes in terms of diarrhoea control. India is the focus of our study.

It is well known that diarrhoea incidence can be brought down by isolating human excreta from living spaces or blocking the infection route through hygienic practices (JICA 2012). Excreta-related pathogens reach human hosts via vectors that use or involve faeces as a medium. For instance, from faeces, the pathogens are transferred to humans either through non-hygienic behaviour or through intermediaries like flies, plants, fish, molluscs, other animals, soil and water. Hygiene behaviour such as the use of toilets, regular washing of hands, maintaining clean living spaces, workspaces and kitchens, using footwear, practising hygienic disposal of stools minimise pathogen transmission. Of course, hygiene behaviour is facilitated if households have access to toilets and non-contaminated water. In short, drinking water, sanitation and hygiene behaviour referred to as the water, sanitation and hygiene (WASH) variables by the United Nations Children's Emergency Fund (UNICEF) are widely acknowledged as being the three main determinants of diarrhoeal diseases, but the impact of their complementarity on disease incidence remains understudied.

Indeed, the central role of access to water and sanitation for sustainable development is now even more confirmed with the formal adoption of the 17 Sustainable Development Goals (SDGs) in September 2015 by the United Nations (UN) General Assembly. Among these, Goal 6 is to ensure availability and sustainable management of water and sanitation for all by 2030. This presents a great challenge for India, because according to WHO/UNICEF (2014), India was in the group of only 45 countries where sanitation coverage was less than 50% and home to the largest population lacking sanitation. Thus, over the last decade, sanitation coverage has captured increasing policy attention and is now exemplified in the national programme called the Swachh Bharat Mission, whose central objective is to eliminate open defecation in India through installation of toilets and triggering of behavioural change.

Sanitation: Impact on Diarrhoea and the Indian Reality

Determinants of Diarrhoea: From a comprehensive survey of the medical and economic literature with respect to low- and middle-income countries, Ramani et al (2012) classify the main correlates of diarrhoeal diseases into five categories: (i) physical environment of the locality (for example, weather, water table, drainage, etc); (ii) level of socio-economic development of the region; (iii) knowledge, resource and asset portfolio of household (level of education of the mother, access to water and sanitation); (iv) behavioural routines of the household (childcare practices and practice of open defecation); and (v) individual host characteristics (age, gender). However, within both the medical and economics literature, studies take determinants as stand alones and examine the impact of each separately on the probability of diarrhoeal incidence—even though most recognise the existence of complementarity between various factors.

Taken together, a cross-country analysis by Günther and Gunther (2010) using 172 Demography and Health Survey data sets from 70 countries finds that water and sanitation infrastructure lowers the odds of children suffering from diarrhoea by 7%–17%. This result has been reconfirmed in the context of Nepal by Pokhrel and Viraraghavan (2004), Zimbabwe by Root (2001), Egypt by Roushdy et al (2012), East Africa by Tumwine et al (2002), Senegal by Bampoky (2013), India by Kumar and Vollmer (2013) and generally of developing countries by Waddington et al (2009), respectively.

In addition to sanitation and water, scholars also confirm that knowledge and practice of hygiene behaviour are important determinants of diarrhoea incidence. Khanna (2008) finds that disease-specific awareness among mothers is likely to reduce the incidence of child diarrhoea in India. Fan and Mahal (2011) find that effects of improved water supply or improved toilets on different diarrhoeal outcomes are not consistent in rural India, though regular handwashing has far stronger impacts.

Many works also consider sanitation and water supply separately. Panda (1997) shows that households with toilet facilities are two-fifths as likely as households which have no such facility to have experienced episodes of diarrhoea. Households that utilise "public tube wells" or "bore wells" as sources for drinking water are three-fifths as likely to have experienced an episode of childhood diarrhoea compared to those that utilise unsafe drinking water. Similarly, Borooah (2004) demonstrates that while inadequate toilet facilities increase the likelihood of diarrhoea by 5% and safe water supply reduces the incidence of diarrhoea by 5%, Jalan and Ravallian (2003) find that the prevalence and duration of diarrhoea among children under five in rural India is significantly lower on average for families with piped water than for observationally identical households without it. Such results are also echoed by Quinn (2009), with respect to Ghana.

Some of the papers also try to identify the type of "water source" and "sanitation facility" that best improves health status. In the Ugandan case, Kasirye (2010) finds that only piped water within the household and access to private covered pit latrines significantly lessen diarrhoea prevalence. Another study by Fuentes et al (2006) also highlights that the health benefits are higher for households that have access to flush toilet rather than pit latrine.

Though these studies identify the nature of the impact of sanitation and drinking water *separately* within a country or across countries, they hint that sanitation alone is not the only one determining factor for child diarrhoea. Indeed, the two surveys on determinants of diarrhoeal diseases (Ramani et al 2012) and the impact of sanitation interventions (Loevinsohn et al 2013 along with Khanna 2008) point out that the risk factors are not only individually correlated with the occurrence of diarrhoea, but they often *jointly* determine the final impact on disease incidence. Similarly, through a meta-analysis of worldwide interventions, Fewtrell et al (2005) highlight that combined water, sanitation, and hygiene programmes will not reduce diarrhoea, if the intervention is piecemeal and/or the water quality is neglected. Huda et al (2012) find that a combined intervention in Bangladesh (SHEWA-B) did not sufficiently improve hygiene behaviours, and hence, diarrhoea was not lowered.

These studies drive home the point that interactions between the determining factors, that is, the impact of complementarity, are as important to measure, as the impact of each individual factor taken by itself. Complementarity can be viewed as a particular form of externality in which the taking of an action by an agent increases the marginal benefits of another action(s) for the same or different agent(s) (Ray 2000). When complementarities are not taken into account in an intervention, it often leads to a coordination failure (Rosenstein-Rodan 1943), lowering impact below than that targeted.

State Efforts to Increase Sanitation Coverage in India: Policy interventions to achieve sanitation coverage in low- and medium-income countries tend to be a mix of two types of programmes (Ramani and SadreGhazi 2014). Under the first type, a top-down, state-funded initiative provides sanitation infrastructure as a merit good to households, on the assumption that availability will lead to usage. Under the second type, sanitation coverage is increased through a slower, bottom-up, demand-driven approach, whereby households are persuaded or accompanied by intermediary organisations to invest in or use sanitation infrastructure. Studies show that the top-down approach is challenging, when there is a weak knowledge base and/or a significant socio-economic or ethnic diversity as public good provision programmes tend to take a "checklist" "one size fits all" approach, without adjustment of the programme to ensure the right fit for a context (Rheinlander et al 2011). Bangladesh is a case study of success of the second type of intervention, where the support of microfinance institutions has facilitated investment in toilets and the participation of non-governmental organisations (NGOs) in creating awareness on the benefits of hygiene behaviour has increased the use of latrines (Hadi 2000).

In India, the central government's investment in sanitation infrastructure was initiated under the Central Rural Sanitation Programme (CRSP) of the Ministry of Rural Development in 1986. Following the first type with supply-driven approach, free or highly subsidised toilets were provided to households assuming that increased coverage would automatically reduce open defecation. However, despite an investment of more than ₹6 billion and the construction of over nine million latrines in rural areas, the Census of 2001 found that only 22% of rural households in India had access to a toilet (GoI 2008). The programme failed to motivate and sustain high levels of sanitation coverage, because of poor implementation coupled with indifference from targeted beneficiaries, who perceived no need to use toilets (UN–DESA 2003; GoI 2008).

Consequently, the Indian government adopted the second type of demand-focused intervention. It went from being a supplier of free toilets, to becoming a financier for public–private partnerships involving NGOs, microfinance companies and other social enterprises who interacted closely with the targeted beneficiaries to provide accompaniment and education for sanitation literacy and use (Ramani and SadreGhazi 2014). The Total Sanitation Campaign (TSC) launched in April 1999, emphasised that information, education and communication (IEC) should precede sanitation construction to ensure sustained demand and behavioural change.

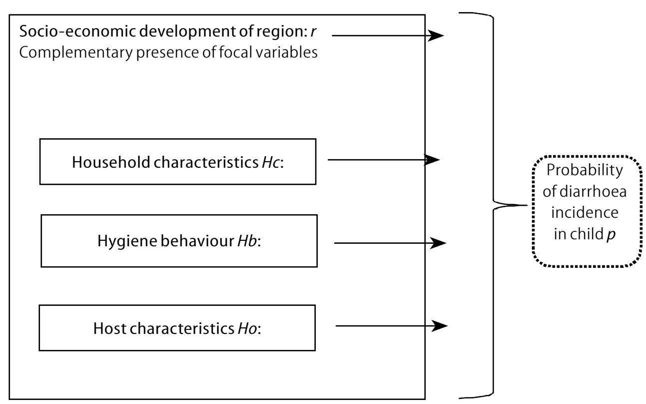
Despite these efforts, India is still far from having complete sanitation coverage status. According to the 2011 Census data collected by the Government of India, of the 247 million households in India, only 47% have their own toilet facilities and out of the remaining 53%, only 3% have access to public toilets. This leaves about half of the households with no option, but to defecate in the open. Moreover, only 3% was from the poorest 20% households of the target beneficiaries of TSC, indicating that the poorest segment hardly benefited from the programme (JMP WHO/UNICEF 2012). It is likely that the bottom 20% of the poor did not have means to "invest first" in toilet-building through own funds or loans and be reimbursed under the TSC programme in the post-construction period. The bottom 20% may indeed require free provision of toilets or community toilets to shift from open defecation.

Translating this into deadweight losses for the economy, a World Bank study (2011) estimates that, the total economic cost of inadequate sanitation in India amounts to a loss of ₹2,180 ($48) per person. Thus, the Indian government is continuing full steam with its national programme to bring about complete sanitation coverage, but diarrhoeal disease has not been lowered significantly yet. In terms of international ranking, India still has the highest burden of child mortality and morbidity related to diarrhoea in South Asia (WHO 2014) and the Disability Adjusted Life Year (DALY) loss due to this disease is still significant. This paradoxical situation clearly proves that increasing the sanitation infrastructure is not a guarantee for lowering diarrhoeal morbidity and calls for a deeper analysis.

Conceptual Framework and Estimation of Empirical Model

From the findings of the literature survey, we start with the premise that the incidence of child diarrhoea is a function of household level characteristics, hygiene behaviour, host characteristics and the complementary presence of water, sanitation and hygiene behaviour within the household and in the locality in which the household is located. Let the probability of incidence of diarrhoea in a child be given by *p*. Further, let the socio-economic development of the region as given by the nature of the joint presence of water, sanitation and observation of hygiene behaviour be given by *r*. Let the vector of household characteristics, including water and sanitation, be *Hc* and similarly let *Hb* give the vector of hygiene behaviour. Finally, let *Ho* refer to the host (that is, potential patient) characteristics. Then all these variables jointly determine the probability of diarrhoea incidence as in Figure 1.

Figure 1: Conceptual Framework



Source: Authors' understanding.

Data: To estimate the model presented in Figure 1, we used the National Family Health Survey (NFHS) of India, which provides information at the state and household level on health status indicators. It is compiled from a very large scale, multi-state and multi-round survey that aims to provide information related to healthcare utilisation and health status of a representative sample of Indian households. The latest version available (NFHS-3) pertains to the period 2005–06 and is based on a sample of 1,09,041 households nationwide. It is the last round of the cross-sectional database available in the public domain. The data set was constructed through interviews requested from women aged 15–49 and men aged 15–54 in the sampled households. From the survey, the "Children Data Set" (IAKR52DT) incorporating both household information and information on illness for all children less than five years of age was used for this paper. In the survey, the incidence of diarrhoea, the focus of our study, was noted by its presence or absence in a child below five years in the two weeks preceding the interview.

Some limitations of the database must also be pointed out. While it is well known that the local environment matters for health, the NFHS sample frame is robust only up to state level, while estimates at districts or substate levels often provide biased values, and hence, the latter could not be considered. In terms of public health infrastructure and hygiene behaviour the only variables available are the ones used in our analysis.

Variables Construction and Estimation Methodology: First, we distinguished between two types of explanatory variables in household characteristics and hygiene behaviour: "focal" and "control." The focal variables were the three main determinants of diarrhoea incidence, that is, the WASH variables, which have been noted in the literature as being highly complementary: existence of toilet facilities within the house premises, source of drinking water and hygiene behaviour of household. The rest were the control variables.

Second, for each focal variable, we not only considered the quantity, but also the quality. For each, we identified a "high" and a "low" quality. For instance, with respect to toilet facilities of household, a flush toilet represents a high quality, and a pit toilet a low quality. Open defecation is automatically listed in low quality. Second, two possibilities exist for the household's "source of drinking water facility": piped water and bottled water signifying high quality and surface water or well indicating low quality. Third, with respect to hygiene, data on the "manner of disposing children's stool" is available. The more hygienic one consists of disposing children's stool in a toilet or burying them underground and the less hygienic one is when they are thrown away, put into the garbage or left open. This quality characterisation was formulated through discussions with experts in the sanitation and healthcare fields.

Third, in order to test the impact of complementarity between the three focal determinants, we constructed a complementarity index between access to toilet, drinking water and disposal of stool as independent variables comprising the WASH index. Complementarity referred to the combined quality of presence of the three major determinants. The presence of best quality was given by 1 and absence of best quality by 0 for each variable. Thus, a complementarity index, given by the sum of the qualities of access to toilet, drinking water and disposal of stool can range between 0 and 3. It assumes the highest or best value 3, when all three variables, namely, access to water, access to sanitation and hygiene practice (disposal of child's stool) assume the best possible categories (that is, the household had flush toilet, used piped or bottled water and children's stools were flushed down the toilet or buried). It assumes intermediate values 1 or 2, when at least one of the three variables is the best possible, but this co-occurs with another one of lower quality in the household. For instance, the household may have access to pipe or bottled water, but it may not have a toilet or the other way round. Finally, complementarity is the lowest or worst at 0, when none of the three variables is of the best possible quality.

Fourth, we identified the different modalities of the remaining control variables. The household asset portfolio was given by the Household Wealth Index (1 = poor, 2 = middle class, 3 = wealthy). The wealth index was constructed from NFHS household-level data, using principal components analysis (PCA) of household ownership of several items. It is acknowledged that the social identity, location of household and level of education of the adult members also influence household behaviour. Thus, the "religion of the household," either Hindu or non-Hindu and "place of residence" of the household, either rural or urban were noted. The "educational level of the child's mother" was taken as the indicator of the knowledge base of the household with respect to health, being either no education, or up to primary school or above primary school level. Another household behaviour considered was nutrition practices. With respect to child nutrition, a continuous variable indicating "duration of breastfeeding" among children below five years was formulated.

Among the individual child level characteristics, vulnerability of a child to disease in developing countries is highly influenced by "gender," whereby female children are given less care than male ones. The "child's birth order number" is crucial too, as the mother becomes more tired and less capable of childcare, while assuming household chores as the number of the pre-existing children increase.

Taking HC_f and HB_f as the household characteristics and hygiene behaviour, respectively with respect to the focal WASH variables; and HC_c and HB_c as the household characteristics and hygiene behaviour, respectively with respect to the control variables, the complementarity index C is computed as in Table 1.

As can be noted, our coding for the complementarity index takes into account both the quality and the complementary presence of the WASH variables. Further, assuming that the control variables, the focal variables and the complementary

Table 1: Focal and Control Variables Considered as Possible Determinants of Child Diarrhoea Incidence

	Household Characteristics with Respect to Focal Variables: HC_f	Hygiene Behaviour with Respect to Focal Variables: HB_f	Complementarity Index: C
Focal Variables - High Quality	Flush toilet (a1=1) Piped water or bottled water (b1=1)	Disposing child stool in toilet or burying it (c1=1)	C= (a1 or a2) + (b1 or b2) + (c1 or c2) with $0 \leq c \leq 3$
Focal Variables - Low Quality	Pit latrine (a2=0) surface water or well water (b2=0)	Throwing child's stool into garbage or in open (c2=0)	
	Household characteristics with respect to control variables: HC_c	Hygiene behaviour with respect to control variables: *HBc*	Host characteristics: *HO*
Control Variables	Household wealth index Religion of Household Place of Residence Mother's Educational Level	Duration of Breastfeeding	Gender Birth Order

Source: : Authors' understanding.

index occur independently of one another at the household level within the region r, we estimated the following two models.

$$p = f^r (HC_f, HC_c, HB_f, HB_c, Ho) \quad ...(1)$$

$$p = f^r (HC_c, HB_c, Ho, C) \quad ...(2)$$

The first model examines the impact of all the drivers of diarrhoea incidence individually without taking into account complementarity. The second model focuses on the role of the control variables and the complementary presence of the WASH variables. Now, it could be argued that hygienic disposal of stools is facilitated by presence of a toilet, and therefore, the three variables need not be independent. But, this is not so, for a child's stool can also be buried, and therefore, the absence of a toilet does not necessarily force the household to adopt unhygienic behaviour.

The indicator for regional socio-economic development, r, was derived using cluster analysis. Since each of the households belongs to a particular state, in the first stage, a "hierarchical cluster analysis" with nearest neighbour method was used to obtain a typology of Indian states according to their level of development vis-à-vis the WASH variables. Then for each cluster, logistic regression analysis was used to estimate Equations (1) and (2) assuming that the explanatory variables are independent. All the statistical analysis was done using the statistical software SPSS 15 and Stata 12.

Results and Analysis

Results of Cluster Analysis: Let us refer to WASH as the joint presence of water, sanitation and observance of hygiene behaviour and use this term to understand the nature of the four groups identified by cluster analysis as given in Table 2.

Cluster 1 comprises the Indian states commonly acknowledged to be the most vulnerable and backward with respect to general socio-economic development. Unsurprisingly, they are the worst in terms of WASH infrastructure, having about 62% of households in the lowest complementary type with all the three focal variables in their worst possible form. Cluster 2 consists of states with middle-level infrastructure, while Cluster 3 contains states with relatively better WASH infrastructure.

Table 2: Typology of Indian States according to the Quality and Complementary Presence of Water and Sanitation Infrastructure and Hygiene Practice

Cluster 1	Cluster 2	Cluster 3	Cluster 4
Chhattisgarh (1,592)	Uttarakhand (1228)	Delhi (1,251)	Meghalaya (1,093)
Odisha (1,781)	Gujarat (1,571)	Mizoram (848)	Nagaland (2,108)
Rajasthan (2,023)	Haryana (1,255)	Sikkim (653)	Arunachal Pradesh (870)
Madhya Pradesh (3,016)	Maharashtra (3,038)	Kerala (1,017)	Assam (1,532)
Uttar Pradesh (7,051)	Himachal Pradesh (995)		Tripura (639)
Bihar (2,320)	Jammu and Kashmir (1,225)		Goa (988)
Jharkhand (1,658)	West Bengal (2,368)		Manipur (1,912)
	Andhra Pradesh (2,292)		
	Tamil Nadu (1,735)		
	Karnataka (2,189)		
	Punjab (1,307)		

The total household sample size in each state is given within brackets.
Source: Analysis of NFHS-3 unit level data.

Cluster 4 is made up of the small states and centrally managed union territories.

Table 3 gives the details of the quality of the complementary presence of WASH across clusters. As one moves up the ladder from Cluster 1 to Cluster 3, the share of all the three good quality focal variables increases from 6.64% to 36.39%. Similarly, the corresponding shares of intermediate categories increase too, while that of worst category (where all focal variables have low quality) drops. What is more interesting is that within the second intermediate category, as the level of WASH improves, the mix of good sanitation quality with either or both bad quality of drinking water and hygiene practices, increases. In Cluster 3, the supposedly best cluster in terms of WASH, the share of households with good sanitation, but with bad quality of other complementary variables constitutes more that 80% of the intermediate category. It is also noteworthy that prevalence of diarrhoea has a clear association with WASH infrastructure at the macro level.

Table 3: Presence of Different Categories of Quality of Complementarity across Different Clusters

	Households in Each Cluster (%)			
	Cluster 1	Cluster 2	Cluster 3	Cluster 4
Complementarity (best)	6.64	25.17	36.39	14.99
Complementarity (intermediate)	31.28	47.42	57.81	59.4
Complementarity (intermediate but with good quality sanitation)	22.16	25.44	47.58	39.07
Complementarity (worst)	62.08	27.41	5.8	25.61
Prevalence of diarrhoea among children under age five years	10.25	9.08	8.26	9.09

Source: Analysis of NFHS-3 unit level data.

Turning now to the sample characteristics of households within each of the four clusters as shown in Table 4 (p 126), we gain more insight. If a household is in Clusters 1, 2 or 4, then it is likely to practise open defecation, not have a toilet, drink water from a well or pumped water, throw away child's stool in an unhygienic manner and live in a rural area. Mothers are likely to have less than primary education (that is, up to fifth class) and breastfeed on average for only 10 days after birth as they are forced to go to work. Households are more likely to be Hindu than non-Hindu in any cluster. However, the ratio of the Hindus is the highest in Cluster 1 and the lowest in Cluster 4. In the latter, the share of Christians within the non-Hindu category dominates. Shares of households with poor wealth index (calculated by the NFHS itself considering the asset positions of the households) decrease across the Clusters 1 to 3. Average birth order of the child surveyed is three in Cluster 1, while it is two in Clusters 2 and 3. Since the NFHS registers the detailed birth history of the children born within five years preceding survey, the birth order of the child represents the fertility behaviour of the mother. Thus children with higher orders are supposed to lack proper childcare.

Results of Logistic Regression Analysis: In order to understand the effects of the different risk factors on childhood diarrhoea, separate logistic regressions were estimated at individual child level in each cluster, with household characteristics, hygiene behaviour and host characteristics in control (recall Equations 1 and 2). The probability of Chi square statistics showed a good fit in all clusters except Cluster 4. Other combinations also did not yield good results indicating that the drivers of diarrhoeal disease are likely to be much more context-specific in each state in Cluster 4, thereby meriting a separate study in itself. Hence, in what follows results on Cluster 4 are not discussed.

Table 4: Features of Households in the Different Clusters (% of Total)

	Cluster 1	Cluster 2	Cluster 3	Cluster 4
Total sample size	15,728	16,658	3,138	6,439
Sanitation facilities				
Flush, etc	29.18	50.84	84.03	54.23
Pit toilets	3.16	2.52	7.78	23.33
No toilet and open	67.66	46.64	8.19	22.44
Drinking water				
Tap, bottle	19.74	59.99	58.89	41.68
Surface, well, etc	80.26	40.01	41.11	58.32
Child stool disposal				
In toilet	15.9	33.88	65.30	34.32
Throwaway	84.1	66.12	34.7	65.68
Duration of breastfeeding				
Average months	0.36	0.32	1.68	0.89
Place of residence				
Rural	67.69	56.45	43.05	63.18
Urban	32.31	43.55	56.95	36.82
Mother's education level				
Less than primary	71.74	53.15	33.01	46.23
Above primary	28.26	46.85	66.99	53.77
Household wealth index				
Poor	53.08	28.18	7.65	30.61
Middle	16.41	18.86	18.04	25.35
Rich	30.51	52.96	74.31	44.04
Religion				
Hindu	81.32	75.78	52.42	40.47
Non-Hindu	18.68	24.22	47.58	59.53
Average childbirth order of child surveyed	3	2	2	3
Sex of child				
Male	51.96	53.15	51.63	50.32
Female	48.04	46.85	48.37	49.68

Source: Analysis of NFHS-3 unit level data.

Table 5 contains the first regression results for each cluster and the full dataset (that is, the estimation of Equation 1). It shows whether the likelihood of child diarrhoea increases or decreases when the variable in question changes. The table reports the odd ratios and standard errors are clustered around states. The relatively low pseudo R^2 for regression results leads us to consider these as associative relationships, making room for many unobserved variables for causal analysis.

Some expected results are confirmed by Table 5. For instance, duration of breastfeeding has a highly negative and significant coefficient in all clusters, showing that the likelihood of diarrhoea decreases as the duration of breastfeeding increases. Religion of households is statistically significant in Cluster 1, implying that in the most backward states, the non-Hindus are more likely to get diarrhoea as compared to the Hindus.

Other results call for more reflections as counter-intuitive findings are revealed on the impact of the WASH and non-WASH variables. For instance, the use of pit toilet and open defecation (relative to flush toilet) is significantly associated with child diarrhoea only in Cluster 1, whereas in the other three clusters as well as in the pooled data with all states, they are insignificant. Drinking water and hygiene behaviour of the households are both insignificant predictors of child diarrhoea in all clusters, thus, indicating a poor association with diarrhoea behaviour.

With respect to the impact of the other control variables, children of urban residents are more likely (coefficient is positively significant) to have diarrhoea in Cluster 1 as compared to rural ones. Furthermore, children of the rich households have significantly lower chances of getting diarrhoea only in Cluster 3, the region with the maximum urban population. Contradicting popular beliefs, mother's education does not have any significant impact in any cluster, a female child is not more likely to suffer from diarrhoea episodes as compared to a male and birth order of child does not matter.

Next, we turn to the impact of complementarity of WASH variables (that is, the estimation of Equation 2). Instead of considering WASH components separately, we examine the impact of their complementary presence and our results are shown in Table 6 (p 127). According to this, complementarity matters in containing diarrhoeal diseases in Cluster 3 but not in Clusters 1 or 2. It is interesting to find that when clubbed together, the pooled data reveals a strong association of complementarity variables with incidence of child diarrhoea, with both the two categories (complementarities 2 and 3 vis-á-vis 1) emerging significant in regression. All control variables have the same

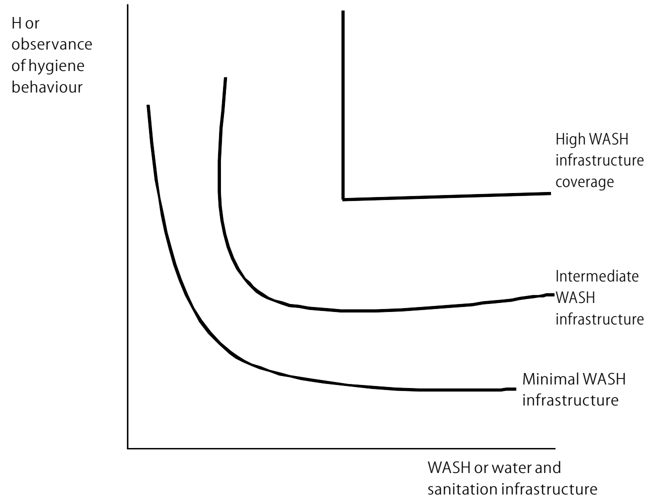
Table 5: Odd Ratios of the Different Determinants of Diarrhoea Incidence

Variables	Odd Ratios				
	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Total
Sanitation (improved toilet in reference) Pit toilet and open (unimproved or no sanitation)	0.237 (0.000)***	0.043 (0.698)	0.057 (0.774)	0.137 (0.586)	0.138 (0.120)
Drinking water (improved reference) surface drinking water and well	-0.151 (0.202)	-0.077 (0.602)	0.353 (0.198)	0.075 (0.715)	0.046 (0.612)
Disposal of child's stool (Hygienic reference) non-hygienic	0.108 (0.34)	0.152 (0.263)	0.174 (0.274)	0.083 (0.607)	0.096 (0.197)
Duration of breastfeeding	-0.021 (0.000)***	-0.022 (0.000)***	-0.013 (0.001)***	-0.002 (0.613)	-0.017 (0.000)***
Place of residence: (rural reference) urban	0.173 (0.024)**	-0.141 (0.454)	0.076 (0.737)	0.258 (0.016)**	0.053 (0.497)
Mother's education: (below primary reference) above primary	0.107 (0.150)	0.139 (0.184)	0.111 (0.575)	0.037 (0.794)	0.097 (0.066)*
Wealth index (low reference) medium	0.135 (0.060)*	0.017 (0.846)	-0.316 (0.319)	0.005 (0.979)	0.061 (0.375)
Wealth index: rich	0.014 (0.896)	-0.037 (0.777)	-0.455 (0.003)***	0.020 (0.944)	0.008 (0.927)
Religion of household: (Hindu Reference) Muslim and others	0.321 (0.000)***	-0.056 (0.557)	0.115 (0.497)	-0.068 (0.704)	0.064 (0.437)
Birth order no	0.007 (0.456)	0.004 (0.828)	0.065 (0.175)	0.016 (0.706)	0.020 (0.071*)
Child's sex: (male reference) female	-0.128 (0.000)**	-0.184 (0.000)***	-0.204 (0.038)**	-0.046 (0.689)	-0.145 (0.000)***
Pseudo R^2	0.13	0.10	0.15	0.024	0.064
F statistics	0.000***	0.000***	0.000***	0.639	0.000***

Diarrhoea=1 if child had diarrhoea in last two weeks and 0 otherwise. P-values of Z-Statistic are in parenthesis. *** denotes significance at 99% confidence level, **at 95% level, and * at 90% level. Standard errors are clustered around states.
Source: Analysis of NFHS-3 unit level data.

kind of impact on diarrhoea incidence as before in the four clusters. Though drinking water and hygiene behaviour is not separately associated with diarrhoea in any of the clusters (as shown in Table 5), their joint presence in WASH variable becomes significant in Cluster 3.

Figure 2: Evolution of Complementarity between WASH Components as a Function of the State of the Regional WASH Infrastructure



Source: Authors' understanding.

Discussion of Results

Our central proposition that complementarity of WASH at both the household and regional level matters for diarrhoea incidence is partially confirmed. Indeed, it is this partial validation that signals the alarm that the one size fits all approach will lead to sub-optimal resource allocation and impact. Our empirical analysis suggests that wherever WASH infrastructure is minimal, the three main determinants of diarrhoeal diseases are strategic substitutes. It is striking that in Cluster 1, while access to improved toilet is strongly associated with less diarrhoea containment significantly, complementarities do not matter (Tables 5 and 6). One explanation for why the sanitation variable is significant "separately" only in Cluster 1 may be because in backward states the percentage of those having better quality sanitation facilities is the least (29%). Thus, within Cluster 1, even if there is investment only in improving access to flush toilets, it will have a significant impact on diarrhoeal morbidity unlike in other clusters. Any infrastructural improvement will also promote inclusive development as findings reveal that the non-Hindus will be particularly benefited also in this cluster.

Table 6: Relative Importance of the Different Determinants of Diarrhoea Incidence Given Joint Presence of Public Health Infrastructure and Hygiene Behaviour (Logistic regressions results)

Variables	Odd Ratios				
	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Total
Complementarity 2 (complementary 3 ref)	0.015 (0.930)	0.177 (0.296)	0.178 (0.127)	0.345 (0.000)***	0.193 (0.026)**
Complementarity 1 (complementary 3 ref)	0.119 (0.513)	0.178 (0.518)	0.655 (0.000)***	0.356 (0.001)***	0.284 (0.037)**
Duration of breastfeeding	-0.021 (0.000)***	-0.022 (0.000)***	-0.013 (0.008)***	-0.002 (0.628)	-0.017 (0.000)***
Place of residence: urban ref: rural	0.18 (0.007)**	-0.118 (0.511)	-0.021 (0.922)	0.246 (0.035)**	0.044 (0.563)
Mother's education:above primary reference above primary	0.086 (0.216)	0.138 (0.206)	0.139 (0.439)	0.038 (0.769)	0.092 (0.094)
Wealth index: medium (low reference)	0.135 (0.052)**	0.023 (0.799)	-0.277 (0.395)	-0.032 (0.874)	0.05 (0.449)
Wealth index: rich (low reference)	-0.057 (0.534)	-0.044 (0.701)	-0.421 (0.000)***	-0.021 (0.938)	-0.027 (0.714)
Religion of household: Muslim and others	0.295 (0.000)***	-0.065 (0.481)	0.127 (0.445)	-0.071 (0.497)	0.055 (0.505)
Birth order no	0.007 (0.511)	0.004 (0.816)	0.059 (0.243)	0.016 (0.709)	0.019 (0.080)*
Child's sex: female	-0.126 (0.000)***	-0.184 (0.000)***	-0.203 (0.127)	-0.050 (0.665)	-0.145 (0.000)***
Pseudo R^2	0.12	0.1	0.14	0.03	0.065
F statistics	0.000***	0.000***	0.000***	0.315	0.000***

Diarrhoea=1 if child had diarrhoea in past 14 days and 0 otherwise. P-values of Z-Statistic are in parenthesis. *** denotes significance at 99% confidence level, **at 95% level, and * at 90% level. Standard errors are clustered around states.
Source: Analysis of NFHS-3 unit level data.

However, as WASH infrastructure improves and reaches a minimum threshold level in each of the three factors, the WASH variables become strategic complements such that the joint presence of sanitation infrastructure, drinking water availability and hygiene behaviour is required to contain diarrhoea. In Cluster 3, according to Tables 5 and 6—the WASH variables have a greater joint impact than as individual determinants. Both quality of drinking water and hygiene behaviour, which individually were insignificant, create an externality in the complementarity variable, which in turn, creates a higher marginal impact in decreasing child diarrhoea (0.056), compared to 0.023 for sanitation in Cluster 1. Essentially, this means that in Cluster 3, if there is investment in both components of public health infrastructure and awareness on hygiene behaviour, then there will be around 56 less cases of diarrhoea per 1,000 children. The insignificant association of either of the WASH variables separately, or jointly in Cluster 2, identifies a difficult zone of intervention when a region is at a middle rung of the WASH development ladder.

The above arguments are summarised in Figure 2. Our results suggest that mothers' education need not be a significant determinant of child diarrhoeal incidences, contradicting our general belief that improvement in mother's education creates better awareness about childcare practices, which translates itself into reduced morbidity among children. However, this could be because the quality of mother's education also matters, and thus, this result seriously questions the quality of education received across the clusters, an issue which has been succinctly represented by the Annual Status of Education Report (2014). Indeed, the studies which found mother's education level to be a good determinant of child diarrhoea like Khanna (2008) have considered awareness of the mothers about healthcare practices, rather than just the formal education level.

The higher incidence of child diarrhoea in urban areas in Cluster 1 too calls for some discussions. Though WHO/UNICEF, 2014 report posits far higher levels of improved sanitation in urban areas (80% globally in 2012) than in rural areas (47%), the hazards and squalor associated with unimproved sanitation are particularly acute in urban areas, where residential densities are high (Mcgranahan 2015). Cluster 1, a typically more rural and backward region of the country, has fewer, but more densely populated towns and cities, lacking proper sanitation and drinking water facilities. The urban population in this region is hence exposed to serious complementary risks of suffering from diarrhoea, primarily due to the high population density and insufficient WASH coverage.

Our results are important in the Indian context, because access to sanitation, water and hygiene behaviour do not have a homogeneous complementary presence in all Indian states. Indeed, it is the reverse. States like Mizoram and Kerala (in Cluster 3) which occupied first and second positions in terms of access to sanitation among 25 states in 2011 are 18th and 25th, respectively in terms of access to improved drinking water. Uttar Pradesh (in Cluster 2), which enjoys third position in terms of access to drinking water, ranks 19th vis-à-vis access to sanitation.[1] Our results point out that one magic bullet of policy intervention in improving access to sanitation will not give homogeneous results across the regions, and diversity in policy dynamics is crucial.

In terms of policy recommendations, our results suggest that in Cluster 1, that is, in states having poor health context, any individual investment in sanitation, availability of water, quality of water or hygiene education will reduce diarrhoea incidence and improve health status. In Clusters 2 and 3, there must be an investment in improving hygiene behaviour, but while ensuring that the complementary presence of access to sanitation, water quantity and water quality are not lowered. Raising the general awareness level of the masses should be targeted through adult education. Indeed, best returns to public investment will be generated only through a joint focus on access to sanitation, water availability, water quality and hygiene behaviour. Investment on one without the other will not reduce diarrhoea incidence as much. As discussed earlier, Table 3 points out that 83.97% of households in Cluster 3 have improved sanitation facilities, but out of them, more than half of the households actually lose the advantage due to coexisting bad quality of drinking water and/or bad hygiene behaviour.

Conclusions

The objective of this paper was to explore why the incidence of diarrhoea among young children below five years has not been lowered in India, despite the substantial investments of the Indian government and international agencies in improving sanitation coverage. In particular, it examines the impact of the complementary presence or absence of WASH, that is, water, access to sanitation and hygiene behaviour on the health outcome of a region in terms of child diarrhoea. A conceptual framework was formulated and tested with household level and state level data for this purpose. Its findings serve to explain the variations in the results noted in the literature and suggest some noteworthy points for policy design for developing countries at large.

It seems worthwhile to view public health as the output of a production function into which many inputs enter. The role of complementarity among inputs in a production function at the firm, sectoral and national level has been explored very well in economics in the context of agriculture, manufacturing and services, but less so in public health outcomes. If we consider public health similarly, planners will need to identify which inputs are substitutable for one another and which are complementary. Identification of focal variables whose complementarity matters significantly for the problem concerned is crucial. For instance, our analysis suggests that in the case of diarrhoea, the crucial variables are the quality and quantity of WASH and its general recommendations for policy design can now be summarised as follows.

First, when WASH infrastructure is least developed, each WASH component can be treated as a substitute of the other. In this case, investment in any of the focal variables will improve health status. However, as WASH infrastructure improves in coverage and quality, the WASH components become strategic complements, and thereafter, uncoordinated or uni-focused programmes will not have much impact. Only a three-pronged strategy targeting all focal variables will maximise returns.

Second, in every WASH variable, it is not only the quantity that matters, but also the quality. This means that technology design of toilets and their fit to environment, quality of water and quality of education that drives hygiene behaviour matter as much or more than simply installing toilets, providing water and running schools.

Third, national and international sanitation drives are unlikely to be effective unless they break the Gordian knot of WASH complementarities holding up the burden of childhood diarrhoea. While any public health programme aiming at increasing just toilet facilities or piped water or hygiene would be easier to implement, it may not achieve the desired results due to their complementary role in diarrhoea incidence. Sanitation drives have to be holistic and promote access to water and hygiene behaviour as well, because disparities at the household level can lower health gains. A household can have improved sanitation, but unimproved drinking water. Gain in one infrastructure may be lost or offset by the lack of another. Besides, not just the water and sanitation infrastructure, but the household-based hygiene behaviour also plays a big role in diarrhoea. Even if a household has an improved toilet within its premises, if its knowledge base is poor, its members may not use water and soap to clean their hands after defecation or they may throw a child's stool anywhere. This way, the gain of improved sanitation is again lost.

This leads us to conclude that a magic bullet for diarrhoea reduction, if indeed, it can be created, has to be necessarily multidimensional, taking into account the quality and synergetic effects of its main drivers. Therefore, the Swachh Bharat Abhiyan, targeting universal sanitation coverage is unlikely to be effective, unless it breaks the Gordian knot of WASH complementarities and WASH quality holding up the burden of childhood diarrhoea.

Note

1 Census of India (2011), Ministry of Home Affairs, Government of India, available at: http://www.censusindia.gov.in/2011-common/census_2011.html.

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